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(54) Abstract Title
Patterned optical elements

(57) A patterned optical element comprises a substrate 10, a uniform alignment layer 12, and a patterned layer of cured, twisted reactive mesogens disposed over the alignment layer 12. The patterned layer has gaps 14' which have no twist disposed between twisted regions 14 so as to define, in the optical element, a plurality of optical regions having different optical properties. The cured, twisted reactive mesogens rotate the polarisation direction of incident linearly polarised light.

Fig. 4

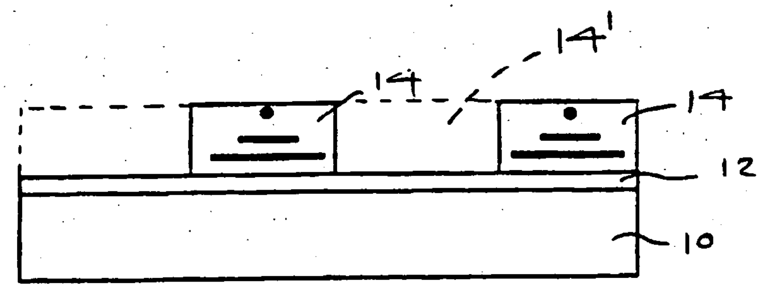

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Fig. 1

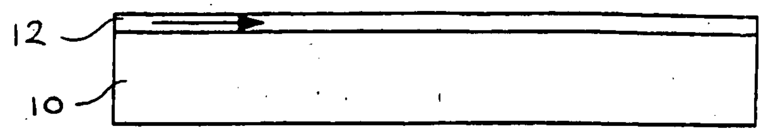


Fig. 2

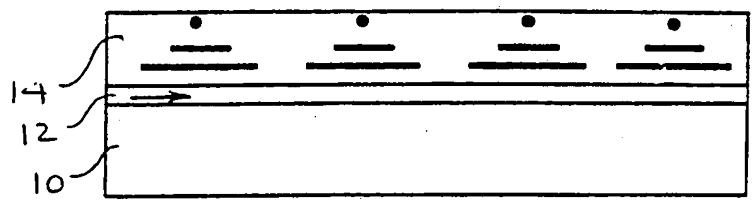


Fig. 3

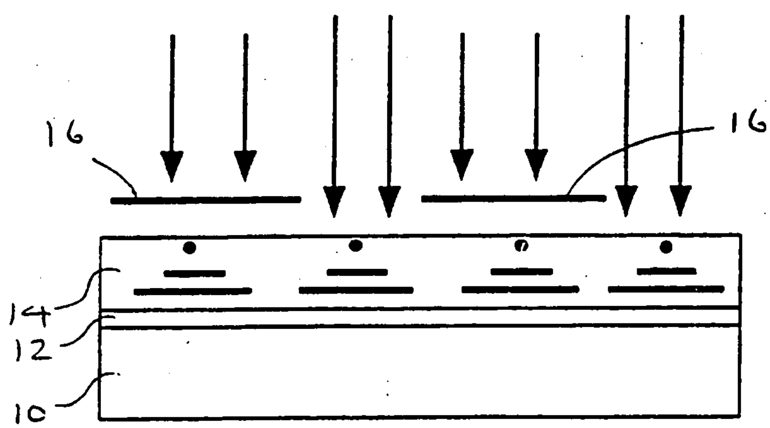


Fig. 4

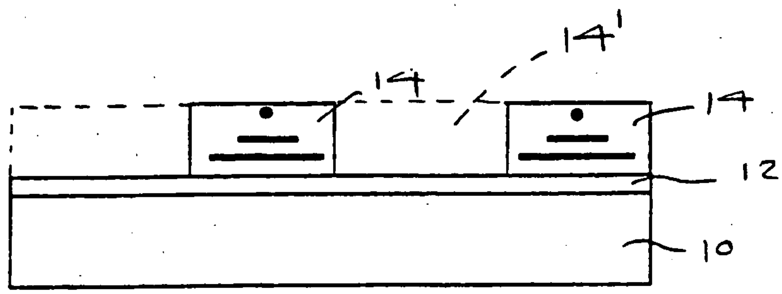


Fig. 5

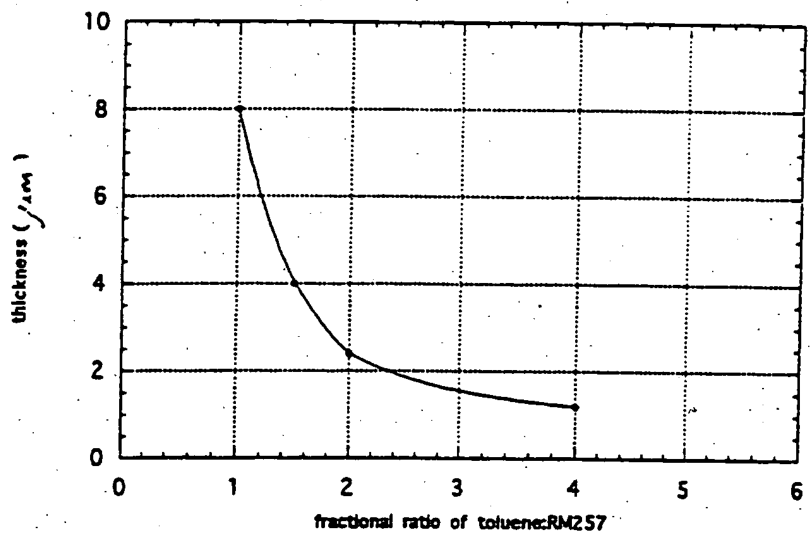
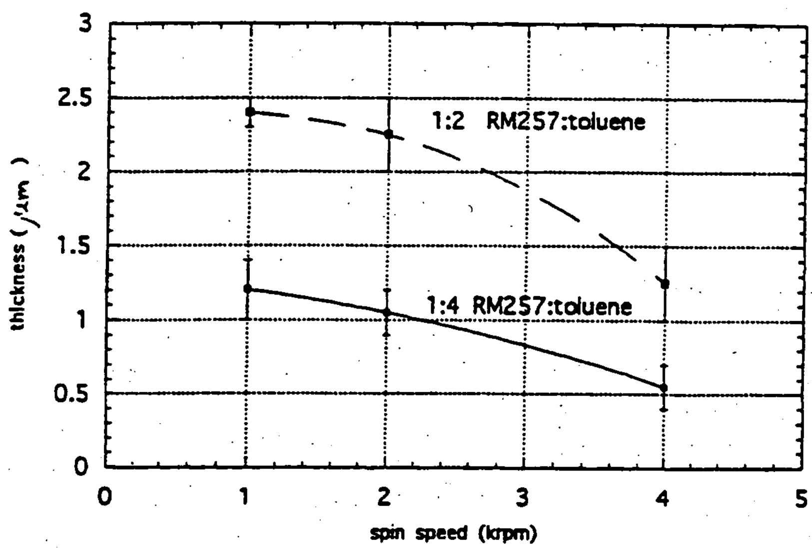

10
8
6
4
2
0
thickness (μm)
0
1
2
3
4
5
6
fractional ratio of toluene:RM257

Fig. 6


3
2.5
2
1.5
1
0.5
0
thickness (μm)
1:2 RM257:toluene
1:4 RM257:toluene
0
1
2
3
4
5
spin speed (krpm)

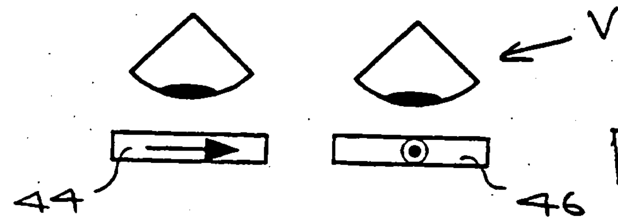
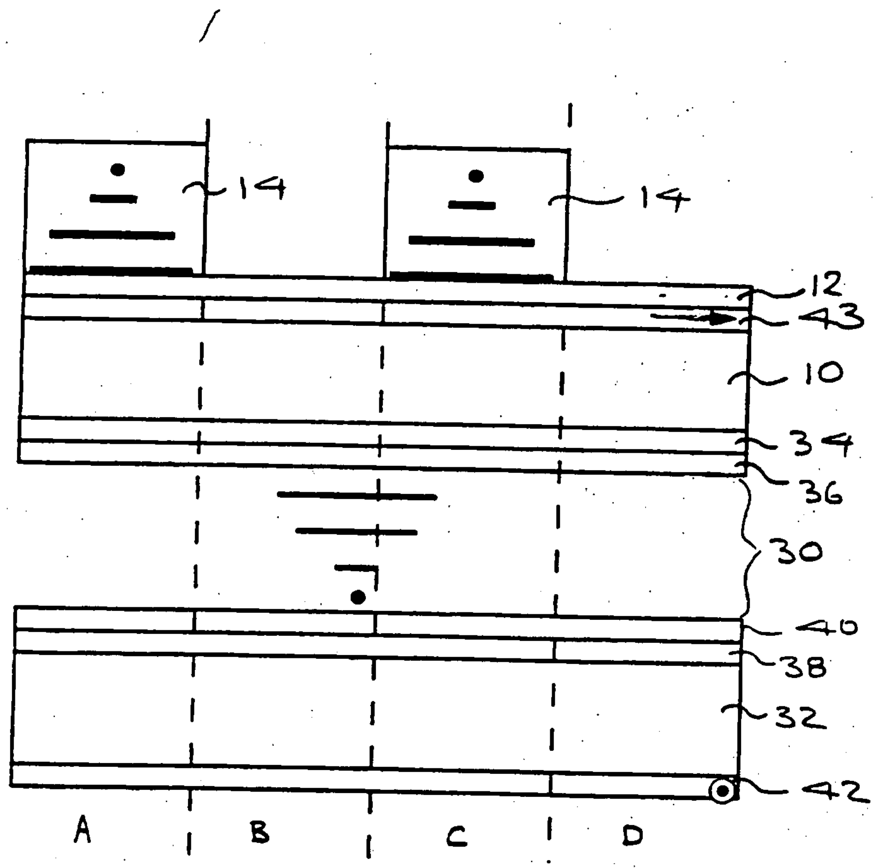


Fig. 7



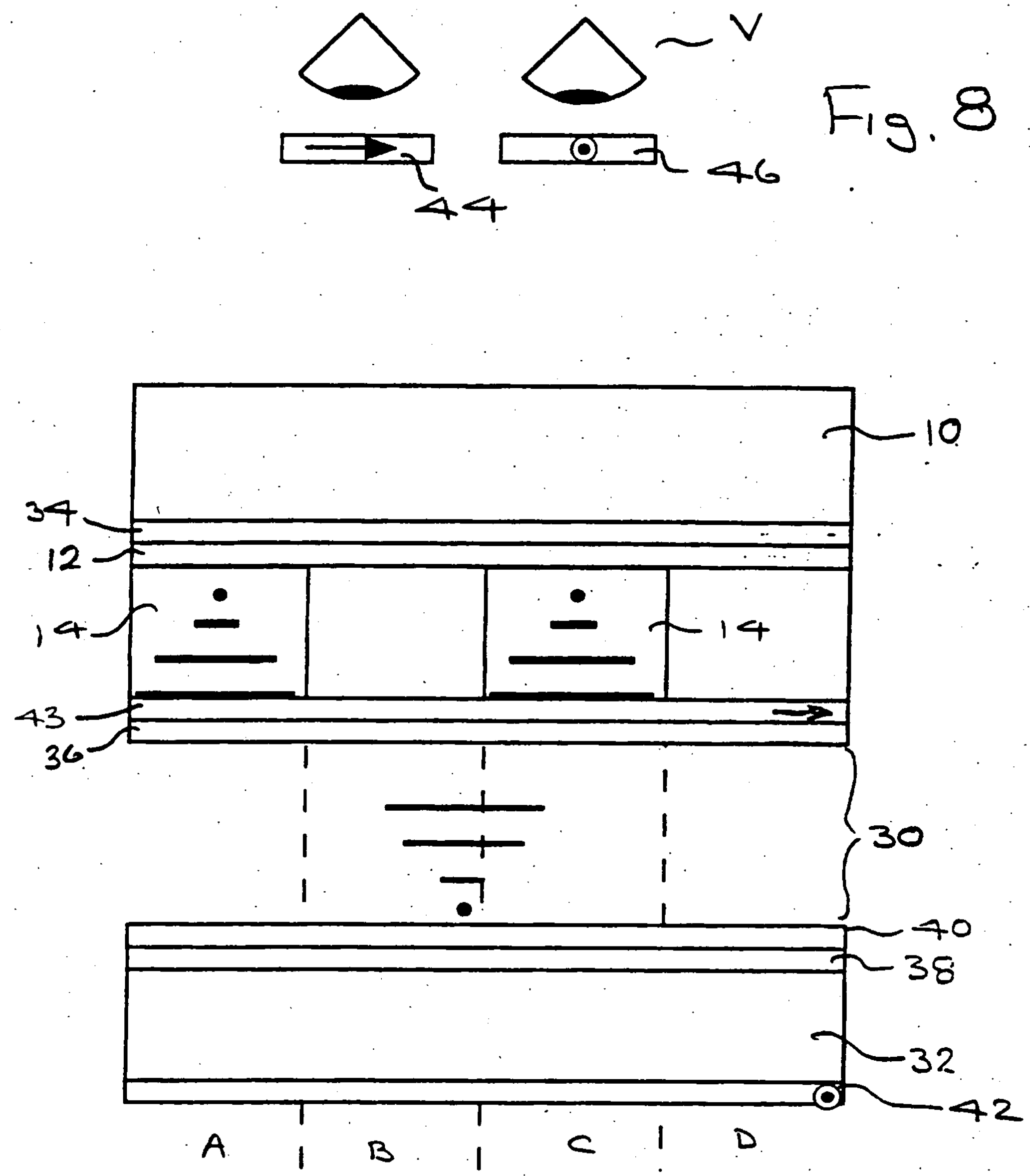


Fig. 8

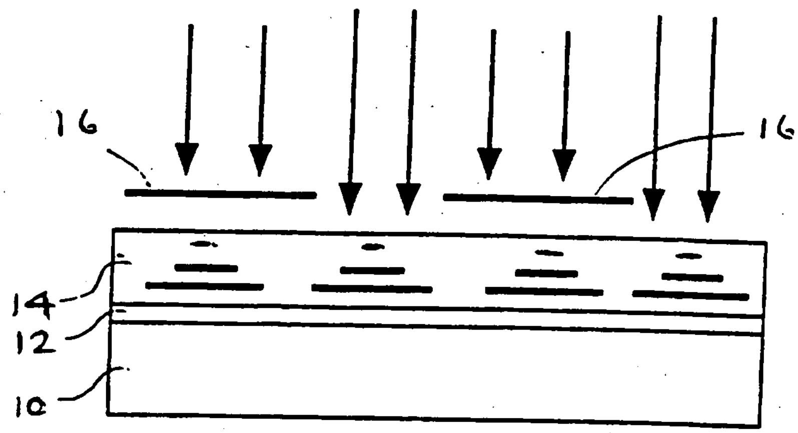


Fig. 9

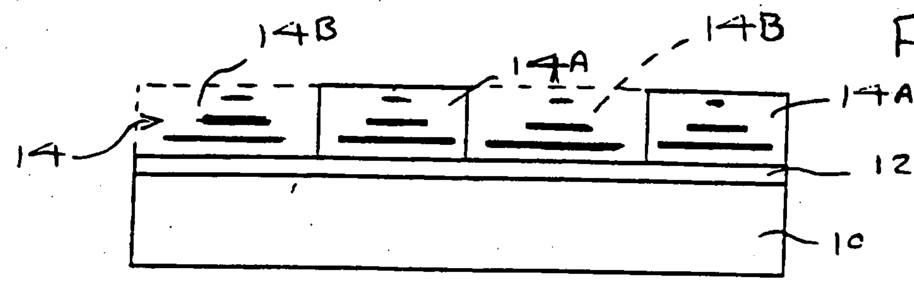


Fig. 10

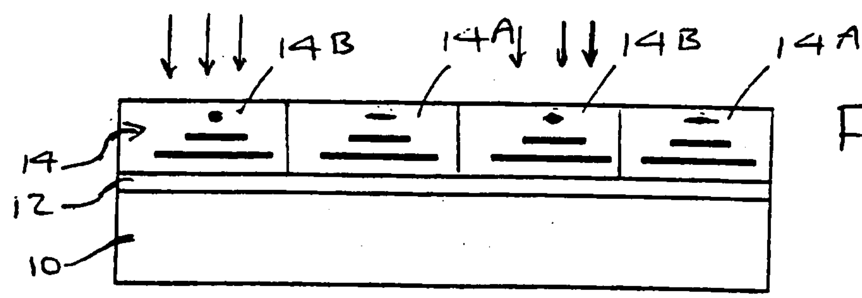


Fig. 11

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PATTERNED OPTICAL ELEMENTS

This invention relates to a patterned optical elements and is more particularly concerned with patterned optical elements having regions which differ in the way which they affect polarised light, and with methods of producing such patterned optical elements. Such patterned optical elements are potentially useful with pixellated display screens (notably 3D liquid crystal display screens) in the fields of television, computer screens and 3D photography for example. Accordingly, this invention also relates to devices incorporating such optical elements

It is known to produce patterned optical elements in a form of patterned polarising sheets. For example, in US-A-5235449, a polarising element having a chessboard pattern of regions having mutually inclined polarisation axis directions is produced by forming an organic thin film which is uniformly orientated in a particular direction on a substrate, followed by providing a polymerisable layer on the thin film, and then selectively polymerising regions of the layer to produce a desired pattern having a predetermined polarisation axis direction followed by removal of the unpolymerised regions and subsequent deposition of another polymerisable layer with patterning to produce regions having a polarisation axis in another direction. The polymerisable layers employed are diacetylene-based.

US-A-5327285 discloses a number of techniques for producing a micro-patterned polarising element where regions have a polarisation direction different from those of other regions. In one procedure, a first polarising film has regions which are selectively removed or bleached to render the regions non-polarising, followed by laminating the first film with a

second film which has been similarly treated but in an inverse manner so that, when the films are laminated together, the required pattern of regions having different polarising directions is provided. In another method, the films are not initially polarised but are selectively polarised in the required regions before lamination takes place. JP-A-63-158525 discloses a similar procedure using PVA films. US-A-5327285 is mainly concerned with polarised films formed of PVA. However, it also discloses the use of a cholesteric liquid crystal polariser for the first film which is masked to expose the required pattern and then treated to provide a pattern of polarised and unpolarised parts, followed by lamination of such sheet to a polariser sheet.

D.J. Broer in Mol. Cryst. Liq. Cryst, 1995, Vol 261, pages 513-523 discloses various thin film architectures incorporating liquid crystal networks which are in situ photopolymerisable to fix the molecular orientation of a liquid crystal phase therein. Reference is made to photopolymerisable nematic networks as well as cholesteric, smectic, ferroelectric and blue phases. Reference is also made to a number of manufacturing techniques of which one is concerned with the photopolymerisation of a liquid crystal monomer between two polyimide-coated substrates of which the rubbing directions are mutually different so as to produce, with the inclusion of a chiral dopant when necessary, a twisted structure useful for manufacturing half wave plates and STN (supertwisted nematic) compensation foils.

D.J. Broer (Supra) also discloses the possibility of carrying out photopolymerisation by modulation of the light intensity in the plane or over the cross-section using masks or interference (holography) techniques, and the manufacture of a chessboard type of structure by

local irradiation of a uni-axially aligned liquid crystal monomer and a subsequent re-orientation of the unexposed area, e.g. by rotation of the direction of the external field, and a flush post-exposure of the total area to polymerise also the remaining monomers. This document also discloses the possibility of altering the molecular ordering in the unexposed areas by a change of temperature so as to form, for instance, anisotropic islands in an isotropic sea. D.J. Broer also discloses that, especially when cholesteric liquid crystal monomeric mixtures are used with a steep temperature dependence of the pitch of the molecular helix, the pitch can be locally altered and coloured patterns can be formed which are useful for patterned reflective colour filters.

M. Schadt et al, Japan J. Appl. Phys., Vol 34 (1995) pages L764 - L767, disclose a patterned optical element comprising an alignment layer formed by producing a photoorientable polymerisable layer and selectively photopolymerising different regions of such layer by selectively masking and exposing to polarised light in different polarisation directions so as to induce different alignment directions to the polymer molecules in the layer. Such layer is then over-coated with a liquid crystal prepolymer layer. The molecules in the liquid crystal prepolymer layer adopt an alignment corresponding to that of the underlying region of the polymer layer. The liquid crystal layer is then polymerised to fix the orientation in the liquid crystal layer so that the different regions affect polarised light passing therethrough differently.

A similar arrangement to this is disclosed in EP-A-0689084 which also discloses the possibility of incorporating a dichroic dye in the liquid crystal prepolymer layer to produce an optical element having regions with different polarisation directions. EP-A-0689084 also discloses the

possibility of introducing a chiral dopant into the liquid crystal monomer layer to produce a selectively reflective cholesteric filter or circular polariser. However, such arrangements require a photopolymerisable alignment layer in which different molecular alignment regions are provided by masking and exposure to polarised light in different polarisation directions. Thus, specialised monomers and directional control over the incident cross-linking UV radiation is required.

It is an object of the present to provide a patterned optical element which can be relatively simply produced without the need for a specialised type of alignment layer or specialised photocuring techniques.

According to one aspect of the present invention, there is provided a patterned optical element comprising an alignment layer having a uniform alignment direction; and a patterned layer of cured liquid crystal monomers (hereinafter called "reactive mesogens") disposed over the alignment layer so as to define, in the optical element, a plurality of optical regions having different optical properties, wherein at least one of the optical regions is defined by regions of the patterned layer in which the cured reactive mesogens are twisted so as to rotate the polarisation direction of incident linearly polarised light.

According to a second aspect of the present invention, there is provided a method of producing a patterned optical element having a plurality of optical regions with different optical properties, comprising the steps of forming an alignment layer having a uniform alignment direction; providing a layer of a twisted reactive mesogen composition on the

alignment layer; and effecting selective curing of regions of the composition whereby to fix the twist in such regions.

In one embodiment, uncured regions of the layer are removed so as to define gaps in the layer which thus have different optical properties to the cured twisted regions remaining in the layer.

Removal of the uncured parts of the layer may be effected by stripping away using a solvent or by any other suitable stripping process, for example by plasma etching. The gaps may be filled with another material (e.g. with a planarising material) having different optical properties to the cured regions to produce a layer of substantially uniform thickness.

As an alternative to removing the uncured regions of the layer as described above, it is also possible to render the uncured regions non-twisting by heating the layer above the temperature at which the reactive mesogens undergo a phase transition from nematic to isotropic. Once the required regions are in the isotropic phase, they can then be cured thus locking them in their non-twisting and non-birefringent state. This has the advantage over stripping away such regions in that it does not require any planarisation steps to produce a layer of uniform thickness.

In another embodiment, a curable reactive mesogen composition is used which exhibits a different twist angle at different temperatures. Thus, by selectively curing different regions of the reactive mesogen composition at different temperatures (e.g. by use of non-heating polymerising radiation such as UV radiation), it is possible to fix different twist angles in different regions of the cured reactive mesogen layer. Thus, in this

embodiment is not essential to leave uncured regions which are subsequently removed so as to leave gaps in the layer, although this may be done if required. By this technique it will be understood that, by appropriately repeating masking and curing at different temperatures, it is possible to produce any desired number of optical regions having different optical properties.

The twisting of the reactive mesogens may be produced by using reactive mesogens which themselves are chiral. However, it is preferred to employ a chiral dopant which serves to cause untwisted reactive mesogens to adopt a twist. This facilitates control over the pitch of the twist, i.e. the distance over which the liquid crystal director twists through 360°.

Most conveniently, the chiral reactive mesogen composition is cured by photopolymerisation.

In a typical example, the twist in certain regions of the cured reactive mesogen layer may be such as to rotate the direction of polarisation of incident linearly polarised light through 90°. Whilst it is well known that a half-wave ($\lambda/2$) plate can be used to "flip" the direction of polarisation of linearly polarised light through 90°, such a half wave plate only has a half-wave retardance at one wavelength of light. The use of guiding-mode optics as in the twisted birefringent materials used in the present invention have the advantage over a half-wave plate device in being much less chromatic. Retardation elements operating over a wide wavelength band are known (see S. Pancharatnam, Proc. Ind. Acad. Sci., Vol. XLI, No. 4, Sec. A, 1955 pages 137 to 144), these tend to make use of multiple waveplates with their optic axes set at certain select angles to

one another. Such multiple elements are relatively difficult to fabricate, particularly in a patterned arrangement.

Thus, the present invention does not require any patterning of the alignment layer. The optical properties of the twisted liquid crystal can be suitably selected by appropriate selection of the thickness of the layer and the birefringence as will be well appreciated by those skilled in the art (see for example C. H. Gooch et al, J. Phys. D: Appl. Phys., Vol 8, 1975, pages 1575 - 1584). Thus, any desired twisted nematic crystal material may be employed for the liquid crystal layer in the optical element of the present invention provided that it is one which is capable of being cured to set the twist and alignment therein.

According to a third aspect of the present invention, there is provided a display device comprising a pair of substrates, a respective alignment layer on a surface of each substrate, a liquid crystal layer disposed between the substrates in contact with the alignment layers, and means for applying a field across selected regions of the liquid crystal layer, in combination with an optical element according to said first aspect of the present invention disposed so that, in use, light which is transmitted through different regions of the liquid crystal layer is incident upon different regions of the element.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figs 1 to 4 show various stages in the manufacture of one embodiment of patterned optical element according to the present invention;

Fig 5 is a graph showing the variation of thickness of a spun layer of a reactive mesogen composition with fractional ratio of toluene to reactive mesogen;

Fig 6 is a graph in which the thickness of a spun layer is plotted against spin speed for two different reactive mesogen compositions containing different relative proportions of reactive mesogen and toluene;

Fig 7 is a schematic illustration of a 3D display device incorporating a patterned optical element according to the present invention;

Fig 8 is a schematic illustration of another 3D display device incorporating a patterned optical element according to the present invention; and

Figs 9 to 11 show various stages in the manufacture of another embodiment of patterned optical element according to the present invention.

Referring now to Figs 1 to 4 of the drawings, a patterned optical element is produced first by providing a transparent glass substrate 10 having uniform optical properties with an alignment layer 12 thereon having a uniform alignment direction, as indicated by the arrow in Fig 1, and uniform optical properties. Such alignment layer 12, in this embodiment, is formed by spin-coating and baking a thin (approximately 50 nm) layer of a polyimide polymer on the substrate 10 and then unidirectionally rubbing the exposed upper surface of the layer 12 with a soft cloth. Other methods of alignment include dip coating, angle evaporation of inorganic materials such as silicon oxide and Langmuir

Blodgett coating with a suitable surfactant. All such methods are well known in the field of liquid crystal technology.

Following the preparation of the alignment layer 12, a layer 14 of a twisted nematic reactive mesogen composition (which may contain a reactive mesogens which are all of the same type or a mixture of different reactive mesogens) is deposited on the alignment layer 12 by spin coating from a solvent, although other methods of producing a layer including dip coating and draw-bar coating may be employed.

The thickness of the layer 14 depends on the eventual desired optical properties, but will normally be in the range of 1 to 10 μm with a twist angle of $\leq 90°$. A suitable reactive mesogen material is the diacrylate material RM257 available from Merck Ltd. However, other reactive mesogens include monoacrylates, methacrylates and vinyl ethers. Such reactive mesogen material is not inherently chiral. Thus, the reactive mesogen composition used to form the layer 14 also contains a chiral dopant which imparts a twist in the reactive mesogen layer.

The reactive mesogens in the layer 14 are thus caused to adopt a twist as shown in Fig 2 across the thickness of the layer 14, with the reactive mesogens in the region of the layer 14 adjacent the alignment layer 12 being aligned parallel to the alignment direction of the latter. In this particular embodiment, the nature of the reactive mesogens, the thickness of the layer 14 and the amount and type of the chiral dopant are all selected so as to induce a 90° twist angle in the reactive mesogen molecules across the layer 14, as shown in Fig. 2.

With the reactive mesogen molecules thus aligned and twisted, the layer 14 is subjected to selective photopolymerisation through mask 16, as shown in Fig 3, to produce the required pattern of cured regions in the layer 14.

Following this, the uncured regions of the layer 14 are dissolved away using an appropriate solvent so as to leave the completed patterned optical element, see Fig 4. As will be apparent from Fig. 4, some of the optical regions in the completed element are provided by the gaps 14' between the remaining cured regions of the layer 14. The gaps 14', having no twisting effect on incident linear polarised light, possess a different optical property to that of the remaining cured layer regions 14 which serve to twist incident linear polarised light through an angle of 90°.

Referring now to Figs. 5 and 6, there is shown the effect on the thickness of the layer 14 of the ratio of solvent to reactive mesogens (Fig. 5) and the spin speed (Fig. 6). In producing the data for Figs. 5 and 6, substrates were used which had been previously been coated with a polyimide (PI2555 -DuPont). Such coating with PI2555 was effected by dissolving the PI2555 in 20 parts by weight of a proprietary solvent (T39039 - DuPont) and filtering the solution down to 0.2 μm using PTFE filters. A few drops of this solution were spun (4 krpm, 40 seconds) onto the glass plates 10 which had been cleaned using a combination of sodium hydroxide solution, de-ionised water and propanol). The substrates were then baked at 90 °C for 30 minutes to drive off excess solvent and then at 250 °C for 1.5 hours to induce imidisation of the PI2555. The polyimide film was then unidirectionally rubbed with a soft cloth to induce unidirectional alignment. A reactive mesogen

composition was used which contained the above-mentioned diacrylate material RM257, toluene as the solvent and approximately 1 to 5 %w/w of a photoinitiator (Daracur 4275 - Ciba Geigy) was included in the reactive mesogen composition which also contained . The composition was filtered down to 0.2 μm particle size through a PTFE filter before spinning onto the pre-coated and rubbed substrate. Spinning was effected for 30 seconds after which the spun layer was cured by ultraviolet illumination under a nitrogen atmosphere. Thus, the exposed surface of the layer 14 was under a nitrogen atmosphere and was not adjacent to another alignment layer.

In a particular example, the layer 14 has an optical thickness of 0.48 μm, which corresponds to the so-called "first minimum condition" which is per se known and used in the design of twisted nematic liquid crystal devices. The optical thickness corresponds to the product of the physical thickness and the birefringence of the twisted birefringent material.

Examples of suitable chiral additives which are commercially available include those which are sold by Merck Ltd under the designation CB15 and R1011 which have twisting powers of about 7.5 μm^{-1} and about 32 μm^{-1}.

In a particular experimental example of the production of layer 14, 1 mg of CB15 was added to 472.2 mg of RM257 (nominally producing a helical pitch of roughly 63 μm), together with 703 mg toluene as solvent and 7 mg Daracur 4265 photoinitiator. The resultant composition was then spun onto layer 12, which was formed of unidirectionally rubbed PI 2555 polyimide, for 30 seconds at about 1 krpm. This produced a layer of about 4 μm thickness which appeared black to the naked eye when

viewed in transmission held between a linear polariser aligned along the rubbing direction of the layer 12, and an analyser set at about 22° to the polariser direction, i.e. the layer 14 produced guiding through about 22°, as expected from the known pitch and thickness of the layer.

The mask 16 may arranged to provide a pixellated array of approximately 100 μm square holes, or it may define long slits of width about 100 μm. Instead of using a mask, the optical interference of a number of laser beams can be used to create a spatially varying irradiation pattern to effect curing of the desired regions of the layer 14.

If desired, the optical element as illustrated in Fig. 4 may have the gaps 14' between the remaining regions of the layer 14 filled with a suitable material such as a so-called "planarising back flow material". Elevated temperature may be used to drive off any residual solvents from earlier stages.

Finally, once all the regions of the layer 14 have been polymerised or stripped away as desired, elevated temperature or suitable solvents can then be used to remove any chiral dopants originally added to the reactive mesogen mixture since the curing or polymerisation process has already fixed the optical state of the liquid crystals. This ensures that such dopants cannot leach into any adjacent layers coming into contact with the layer 14 in use.

It is also within the scope of the present invention to use a twisted reactive mesogen composition having a twist which is temperature dependent, enabling different regions of the layer to have different twist angles depending upon the temperature of which they were cured. In

one example, there is used a chirally doped nematic liquid crystal whose pitch is temperature dependent such that the pitch diverges (i.e. approaches infinity) as the smectic-A phase is approached. The smectic-A phase consists of liquid crystal molecules confined within layers which, as such, cannot support twist. In a second example, two different chiral nematic materials of opposite handedness are mixed to provide a pitch compensated mixture at a certain temperature, T. If the two components have a twisting power with different temperature variation characteristics, raising the temperature above T can cause one handedness to dominate, giving one direction of twist to the mixture, whilst lowering the temperature below T can induce the opposite handedness of twist. For example, it is known that a mixture of an approximately 90% w/w of a 1-alkoxy propane with 10 %w/w of propionitrile at about 115°C produces an infinite pitch mixture. Raising the temperature by about 2°C induces a right-handed chiral nematic structure, whilst lowering the temperature by about 2°C induces a left-handed chiral nematic structure. Thus, it is within the scope of the present invention to cure certain regions of the reactive mesogen layer at a first temperature to produce a desired pattern of cured regions, and then to cure other regions (which may or may not constitute all of the remaining areas) of the layer at a second temperature which is different to the first temperature and which produces a different pitch twist and/or an opposite handed twist to that which is produced at the first temperature.

There are also some individual materials known which, of their own accord, show a helical pitch inversion at some temperature. An example of such a material is 18,19,21,27-tetranorcholesteryl anisoate, see H. Stegemeyer et al, Z. Naturforsch., 44a, 1127-1130, (1989).

Referring now to Fig. 7 of the drawings, the optical element described above with reference to Figs. 1 to 4 is incorporated into a twisted nematic liquid crystal display device having a 90° twisted nematic liquid crystal layer 30 disposed between the substrate 10 and a further substrate 32. On the opposite side of the substrate 10 to the alignment layer 12 (i.e. on the side facing the liquid crystal layer 30), the substrate 10 is provided with a transparent, patterned electrode layer 34 and a rubbed polyimide alignment layer 36 for the liquid crystal layer 30. Likewise, the substrate 32 is provided with a transparent, patterned electrode layer 38 and a rubbed polyimide alignment layer 40 for the liquid crystal layer 30. The alignment layers 36 and 40 are mutually perpendicularly rubbed so that the alignment direction of the layer 36 lies in the plane of the drawing whilst the alignment direction of the layer 40 is perpendicular to the plane of the drawing. The alignment layer 12 has its alignment direction parallel to that of the alignment layer 36.

In accordance with per se well known practice, the patterned electrode layers 34 and 38 enable individually controllable electrical fields to be applied independently to regions A, B, C and D.

On the opposite side of the substrate 32 to the layers 38 and 40, there is provided a linear polariser 42 whose polarisation axis extends perpendicular to the plane of the drawing. A linear polariser or analyser 43 is provided between the substrate 10 and the alignment layer 12. The polarisation axis of the analyser 43 extends in the plane of the drawing, i.e. perpendicular to the polarisation axis of the linear polariser 42.

As will be appreciated from Fig. 7, the regions 14 of the optical element are aligned with regions A and C of the device, whilst the regions B and D are aligned with the gaps between the regions 14 of the optical element.

The device is intended to be used in conjunction with a pair of glasses worn by a viewer V so that the right eye lens 44 of the glasses has a polarisation direction extending in the plane of the drawing, whilst the left eye lens 46 has a polarisation direction extending perpendicular to the plane of the drawing.

From a consideration of the polarisation state of light passing through the various polarisers and other optically active layers in the device, it will be apparent that the left eye of the viewer will always see optical extinction in the regions A and C of the device. Thus, the image seen by the left eye is determined by the voltage applied to the liquid crystal layer 30 via the electrodes 34 and 38 in the regions B and D. Similarly, the picture seen by the right eye is dictated by the state of the regions A and C. Thus, the device can be made to display simultaneously independent images for the left eye and right eye of the viewer and hence give the illusion of a 3-dimensional image.

Referring now to Fig 8, the display device is similar to that of Fig 7 and similar parts are accorded the same reference numerals. In this embodiment, all of the various layers, except for linear polariser 42, are fabricated internally of the cell defined between substrates 10 and 32. It will therefore be seen that analyser 43 is disposed between alignment layer 36 and the layer 14 whose alignment layer 12 is disposed adjacent to electrode layer 34. Such an arrangement ensures that the optically

active layers 14 and 30 are closer together than in the device of Fig 7. This reduces parallax.

In a further alternative, optical quarter wave retarders are used to create opposite-handed circular polarisation states rather than two mutually perpendicular linear polarisation states. This is for use in conjunction with glasses where the individual lenses are circular polarisers of opposite handedness rather than linear polarisers as described above with reference to Fig. 7 or Fig 8.

It will further be appreciated that, *mutatis mutandis*, the optical element as described above can be used in conjunction with 3D photographic images.

Referring now to Figs 9 to 11, the arrangement is similar to that of Figs 1 to 4 except that the layer 14 of twisted nematic reactive mesogen composition is one whose twist varies with temperature. The structure illustrated in Fig 9 is produced in a similar way to that described above in relation to Figs 1 to 3 except that photopolymerisation through mask 16 is effected at a temperature at which the twist in the layer 14 is less than 90°. As a result, the structure of Fig 10 is obtained wherein regions 14A are polymerised regions where the twist has been fixed, whereas regions 14B are unpolymerised regions having the same twist as in the regions 14A.

Referring now to Fig 11, photopolymerisation of the regions 14B is effected at a temperature at which a 90° twist in the previously unpolymerised regions 14B occurs so as to polymerise said regions and thereby fix a twist therein which is different to that in regions 14A. It is

possible to perform one of the above photopolymerisation steps at a temperature at which there is no twist in the layer 14 so as to produce some regions of the layer 14 with twist and other regions with no twist.

CLAIMS

1. A patterned optical element comprising an alignment layer having a uniform alignment direction; and a patterned layer of cured reactive mesogens disposed over the alignment layer so as to define, in the optical element, a plurality of optical regions having different optical properties, wherein at least one of the optical regions is defined by regions of the patterned layer in which the cured reactive mesogens are twisted so as to rotate the polarisation direction of incident linearly polarised light.

2. A patterned optical element as claimed in claim 1, wherein there are gaps in the layer having different optical properties to the cured twisted regions in the layer.

3. A patterned optical element as claimed in claim 2, wherein the gaps are filled with a material having different optical properties to the cured regions of the layer.

4. A patterned optical element as claimed in claim 1, wherein the layer has further cured regions with different optical properties to the first-mentioned cured regions.

5. A patterned optical element as claimed in claim 4, wherein the further cured regions include regions having a different twist to that of the first-mentioned cured regions.

6. A patterned optical element as claimed in claim 5, wherein the further cured regions include regions having no twist.

7. A patterned optical element as claimed in claim 5, wherein the further cured regions include regions having an opposite twist to that of the first-mentioned cured regions.

8. A patterned optical element as claimed in any preceding claim, wherein the reactive mesogens are chiral.

9. A patterned optical element as claimed in any preceding claim, wherein the reactive mesogens have a twist imparted thereto by a chiral dopant included in a reactive mesogen composition used to form the cured reactive mesogen layer.

10. A method of producing a patterned optical element having a plurality of optical regions with different optical properties, comprising the steps of forming an alignment layer having a uniform alignment direction; providing a layer of a twisted reactive mesogen composition on the alignment layer; and effecting selective curing of regions of the composition whereby to fix the twist in such regions so that the latter rotate the polarisation direction of incident linearly polarised light.

11. A method as claimed in claim 10, further comprising the step of removing uncured regions of the layer so as to define gaps in the layer.

12. A method as claimed in claim 11, further comprising the step of filling the gaps with another material having different optical properties to the cured regions.

13. A method as claimed in claim 10, wherein uncured regions of the layer are rendered non-twisting by heating the layer above the

temperature at which the reactive mesogens undergo a phase transition from nematic to isotropic, and then curing such regions.

14. A method as claimed in claim 10, wherein the curable reactive mesogen composition exhibits a different twist angle at different temperatures, and selective curing of different regions of the reactive mesogen composition at different temperatures is effected so as to fix different twist angles in different regions of the layer.

15. A method as claimed in any one of claims 10 to 14, wherein the reactive mesogens are chiral.

16. A method as claimed in any one of claims 10 to 14, wherein a chiral dopant is included in the reactive mesogen composition.

17. A method as claimed in any one of claims 10 to 16, wherein the chiral reactive mesogen composition is cured by photopolymerisation.

18. A display device comprising a pair of substrates, a respective alignment layer on a surface of each substrate, a liquid crystal layer disposed between the substrates in contact with the alignment layers, and means for applying a field across selected regions of the liquid crystal layer, in combination with an optical element as claimed in any one of claims 1 to 9 disposed so that, in use, light which is transmitted through different regions of the liquid crystal layer is incident upon different regions of the element.

The Patent Office

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Claims searched:	1 to 18	**Date of search:**	29 July 1997

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Other: ONLINE EDOC WPI JAPIO INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0634674 A2 (KAISER)-see abstract	1, 8
A	EP 0444703 A2 (HITACHI)-see abstract	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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